Scientific Paper

Trophic composition of edaphic macrofauna in animal husbandry systems in the Dry Corridor of Nicaragua

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Abstract

Objective: To characterize the trophic composition of soil macrofauna in two animal husbandry systems in four municipalities located in the Dry Corridor of Nicaragua.

Materials and Methods: The study area comprised the municipalities Rivas, Belén, La Conquista and Diriamba, all located in the Dry Corridor of Nicaragua. In each municipality four farms were evaluated: two with conventional animal husbandry systems and two with silvopastoral systems. Rivas and Belén, where there was only one farm of each system, were excepted. The study lasted eight months and the sample collection of the edaphic macofauna was carried out every 60 days. The collected specimens were identified to the taxonomic category of families. The biological activity was determined through the grouping into soil engineers, predators, herbivores and detritivores.

Results: The family composition was different between systems, with higher richness in the silvopastoral system, where six classes, 15 orders and 33 families were found. A total of 11 593 macrofauna individuals were recorded in the silvopastoral system, higher value than the conventional one, where 3 062 were found. The difference between systems was marked by the number of individuals found in the *Formicidae* and *Termitidae* families (4 150 and 2 126 individuals/m^2, respectively), which represented 54 % of the total individuals present in the silvopastoral systems.

Conclusions: The highest family richness and quantity of individuals were obtained in the silvopastoral system, which proves its importance in animal husbandry exploitations.

Keywords: trophic composition, density of organisms, biodiversity, macrofauna

Introduction

Soil degradation is one of the most serious effects of the crisis of natural resources at different scales. The animal husbandry sector is labeled as unsustainable, due to the fact that the conventional animal husbandry model causes biodiversity losses and overexploitation of natural resources (Ramírez and Fernando, 2014).

Huybrechs *et al.* (2015), when conducting studies in Nicaragua reported that, in animal husbandry systems, the soil layer is degraded due to the action of animal trampling and because of intensive grazing, which erodes the topsoil, decreases natural fertility and present biotic communities.

The functioning of agrosystems depends on spatial and temporary designs that promote synergies between the biodiversity components of the soil, which condition key ecological processes, such as biotic regulation, nutrient recycling and productivity (Montagnini, 2014).

According to Cabrera-Dávila (2012), the biological diversity resent in the soil has different functions, which contribute to improve its chemical and physical composition. Particularly, the edaphic macrofauna participates in many processes, promoting or affecting plant growth, as well as productivity (Masin *et al*., 2017).

In a study conducted by Chávez-Suárez *et al*. (2016), the importance of some classes and orders in soil transformation (*Annelida: Oligochaeta*), pore formation (*Insecta: Hymenoptera, e Isopoda*) and trituration of plant remains (*Coleoptera, Diplopoda, Isopoda, Gastropoda*), has been emphasized. Understanding the functions of the edaphic macrofauna allows to determine its contribution to sustainability, which turns it into an important indicator at system level. Chávez-Suárez *et al*. (2016) stressed the macrofauna usefulness in the evaluation of soil conservation or disturbance status.

According to Ramírez-Suárez *et al*. (2018), in animal husbandry systems, the knowledge of edaphic biota has particular interest, due to the functions it performs in subsystems that are related to cattle feeding,

Received: May 28, 2019
Accepted: December 22, 2019

How to cite a paper: Gutiérrez-Bermúdez, C. del C.; Mendieta-Araica, B. G. & Noguera-Talavera, Á. J. Composición trófica de la macrofauna edáfica en sistemas ganaderos en el Corredor Seco de Nicaragua. *Pastos y Forrajes*. 43:30-37, 2020.

where it participates in litter decomposition, organic matter mineralization and structural changes of the soil.

The benefits of silvopastoral systems towards the soil resource have been approached by Murgueitio *et al*. (2013), in terms of the increase in carbon content, moisture retention, nutrient recycling and biological activation due to the improvement of plant cover and diversification. This is translated, in turn, into the increase of the symbiotic efficiency of edaphic macrofauna, which allows to establish trends about the productive potential of the milk and beef herd (Rosero *et al.,* 2018). The objective of this study was to characterize the trophic composition of soil macrofauna in two animal husbandry systems, belonging to four municipalities, located in the Dry Corridor of Nicaragua.

Materials and Methods

Geographical location of the study sites. The research was conducted between June, 2017, and February, 2018, period which represented the optimum season for the establishment of protein banks, corresponding to the rainy season (May to November). The study area comprised the Rivas, Belén, La Conquista and Diriamba municipalities, all located in the Dry Corridor of Nicaragua. In each municipality four farms were evaluated: two with conventional animal husbandry systems and two with silvopastoral systems (SPS) of protein banks, aimed at cut and carry. Rivas and Belén were excepted, where there was only one farm of each system (table 1).

Edaphoclimatic characteristics of the evaluated areas. According to data reported by INETER (2017), the temperatures oscillated between 32 and 35 ºC, and the annual rainfall, between 1 500 and 1 750 mm. Rivas and Belén were the municipalities that recorded lower temperatures and rainfall.

In each of the evaluated sites, random sampling was carried out in the plots in order to take samples of the heterogeneity of conditions in the soil. Silvopastoral systems are located in animal husbandry farms, where the work is done with grazing lactating cows, of the Swiss Brown and Brahman breeds. As herbaceous stratum the grasses: *Andropogon gayanus* Kunth*, Hyparrhenia rufa* (Nees) Stapf and *Dichantium aristatum* (Benth) prevail. In addition, there are 360-m^2 (12 x 30 m) protein banks. From the species *Leucaena leucacephala* (Lam.), *Cratylia argentea* (Desv.) *o Kuntze, Gliricidia sepium (*Jacq*), Guazuma ulmifolia* (Lam.) or *Moringa oleifera* (Lam.), at least one is established at a distance of 1 m between plants and rows. At the moment of planting, organic fertilization was carried out with 0,5 kg of compost in each seedling. This fertilization was repeated 35 and 75 days after establishment. After planting, at 60 days, manual control of the main weeds present (*Cyperus rotundus* L, *Euphorbia graminea* Jacq, *Mimosa pudica* L and *Sida acuta* Burm) and one uniformity cut, at a height of 60 cm over the soil, were performed.

The SPS did not receive irrigation. For management purposes, they were considered fully established eight months after they were planted. They were managed with the cut and carry approach. The biomass was cut 60 cm over the soil, every two months, to supply fresh pasture for the animals.

Table 1. Geographical location of the animal husbandry systems.

Municipality	System	North longitude	West latitude	Altitude, m.a.s.l.
Rivas	SPS	11° 25’ 15.4”	85° 50’ 35.6”	79
Belén	SPS	11° 37’ 35.4”	85° 57’ 49.8”	80
La Conquista	SPS	11° 42’ 55.2”	86° 10’ 19.8”	198
La Conquista	SPS	11° 49’ 23.2”	86° 11’ 09.5”	328
Diriamba	SPS	11° 39’ 17.6”	86° 19’ 09.7”	19
Diriamba	SPS	11° 44’ 33.8”	86° 21’ 14.7”	77
Rivas	Conventional	11° 21’ 12.9”	85° 50’ 58.1”	67
Belén	Conventional	11° 32’ 19.4”	85° 54’ 47.8”	59
La Conquista	Conventional	11° 10’ 22.8”	85° 50’ 57.6”	127
La Conquista	Conventional	11° 47’ 15.0”	86° 10’ 47.0”	358
Diriamba	Conventional	11° 48’ 35.3”	86° 20’ 03.3”	255
Diriamba	Conventional	11° 47’ 25.5”	86° 22’ 22.8”	94

The conventional systems consist in animal husbandry farms, in which animal feeding depends mainly on grazing, in areas with no less than three years of establishment and cover percentages higher than 80 %. The prevailing pastures are *Andropogon gayanus* Kunth*, Hyparrhenia rufa* (Nees) Stapf and *Dichantium aristatum* (Benth). The herd was composed by milking cows, of the Swiss Brown and Brahman breeds. Grazing followed a schedule of eight days of occupation and 22 days of resting in each paddock. These conventional systems did not receive irrigation or fertilization. The mean stocking rate in the systems was 0,7 LAU/ha. The soil characteristics in the evaluated areas are shown in table 2.

Collection and processing of the edaphic macrofauna. The collection of edaphic macrofauna samples was carried out between June 10, 2017, and February 20, 2018. The object of study was not the differences between seasons, but the cumulative during the essay. Sampling was performed every 60 days. The methodology proposed by the Tropical Soil Biology and Fertility International Program (Lavelle *et al*., 2003) was used. From each system two soil monoliths were extracted to determine the physical-chemical properties. The edaphic macrofauna sampling was conducted at three depths (litter, 0-10 cm and 10-30 cm), considering that it is in them where there is higher biological activity (Castner, 2001).

The collected specimens were deposited in vials with 70 % alcohol for their transfer to the Entomology Laboratory of the School of Agronomics of the National Agricultural University, where their identification was carried out to the taxonomic category of family. For such purposes the keys proposed by Castner (2001), Cabrera-Dávila *et al*. (2011), Roldan (1988), and Cabrera-Dávila (2012) were applied. The populations and dominance of the soil macrofauna were obtained from the transformation of the number of individuals per monolith into number of individuals per square meter (ind/m^2). Likewise, the ecological function was assigned to each family. The individuals were classified as detritivores, soil engineers, herbivores and predators (Cabrera-Dávila *et al*., 2011).

Results and Discussion

The composition of the families was different between systems, with higher richness in the SPS (31 families), compared with the conventional one (23 families). In both, the family *Formicidae*, belonging to the group soil engineers, was the most representative (table 3).

The families associated to detritivorous organisms showed low populations (ind/m^2), *Porcellionidae* being common between systems, with highest density with regards to other families of detritivores. The family composition of the herbivore group was different between systems. The highest number was recorded in the SPS (10 families), compared with those identified in the conventional system (five families).

In the SPS, the family composition was associated to functionality related to changes in the soil structure, determined by families from the group of

Table 2. Physical-chemical properties of the soil in animal husbandry systems.

Department	Municipality	System	pH	OM, %	N, %	P, ppm	K, meq/100 g soil	Texture
Rivas	Rivas	SPS	5,63	4,78	0,24	3,60	1,64	L-cla
	Belén	SPS	6,46	2,99	0,15	14,07	1,04	Cla
Carazo	La Conquista	SPS	7,62	4,04	0,20	96,38	2,91	Cla
	La Conquista	SPS	5,68	3,83	0,19	0,85	1,86	L-cla
	Diriamba	SPS	6,73	3,20	0,16	1,39	0,22	L-cla
	Diriamba	SPS	6,19	3,41	0,17	12,92	1,82	L-cla
Rivas	Rivas	Conventional	6,43	3,78	0,19	0,37	1,03	Cla
	Belén	Conventional	6,01	4,36	0,22	2,05	0,79	Cla
Carazo	La Conquista	Conventional	5,90	4,73	0,24	1,66	1,84	Cla
	La Conquista	Conventional	6,31	2,47	0,12	1,12	0,52	Cla
	Diriamba	Conventional	6,20	3,83	0,19	5,97	0,97	Cla
	Diriamba	Conventional	5,80	3,79	0,19	5,97	0,97	Cla

L-cla: Clayey loam; Cla: Clayey, pH; OM: organic matter; N: nitrogen; P: phosphorus; meq: milliequivalent; ppm: parts per million.

Table 3. Taxonomic classification, trophic role and diversity of the edaphic macrofauna for animal husbandry systems.

Class	Order	Families	Number of individuals		Relative density, %		Trophic role
			Conventional	Silvopastoral	Conventional	Silvopastoral	
Clitellata	*Haplotaxida*	*Lumbricidae*	144	768	4,7	6,6	Engineers
Arachnida	*Araneae*	*Salticidae*	75	227	2,4	2,0	Predators
		Theraphosidae	80	423	2,6	3,6	Predators
Diplopoda	*Scolopendro-morpha*	*Scolopendridae*	102	522	3,3	4,5	Predators
Insecta	*Blattodea*	*Blatellidae*	48	32	1,6	0,3	Engineers
	Coleoptera	*Buprestidae*	16	48	0,5	0,4	Detritivores
		Chysomelidae	22	90	0,7	0,8	Herbivores
		Cleridae	NR	16	NR	0,1	Predators
		Coccinellidae	19	77	0,6	0,7	Predators
		Curculionidae	16	16	0,5	0,1	Herbivores
		Elateridae	48	336	1,6	2,9	Predators
		Elmidae	50	350	1,6	3,0	Detritivores
		Lampyridae	13	51	0,4	0,4	Predators
		Scarabaeidae	207	651	6,8	5,6	Herbivores
		Tenebrionidae	74	70	2,4	0,6	Detritivores
	Dermaptera	*Forficulidae*	104	120	3,4	1,0	Predators
	Diptera	*Stratiomyidae*	20	28	0,7	0,2	Detritivores
	Hemiptera	*Aphididae*	NR	72	NR	0,6	Herbivores
		Cercopidae	NR	76	NR	0,7	Predators
		Gelastocoridae	NR	88	NR	0,8	Predators
		Lygaeidae	34	30	1,1	0,3	Predators
		Reduviidae	NR	116	NR	1,0	Predators
	Hymenoptera	*Formicidae*	1 258	4 150	41,1	35,8	Engineers
		Mutillidae	290	174	9,5	1,5	Predators
		Vespidae	NR	32	NR	0,3	Herbivores
	Lepidoptera	*Noctuidae*	12	20	0,4	0,2	Herbivores
		Sphingidae	NR	32	NR	0,3	Herbivores
	Orthoptera	*Acrididae*	48	16	1,6	0,1	Herbivores
		Gryllidae	NR	32	NR	0,3	Herbivores
Gastropoda	*Mesogastrópoda*	*Planorbidae*	16	48	0,5	0,4	Herbivores
	Pulmonata	*Helicidae*	64	384	2,1	3,3	Herbivores
		Veronicellidae	NR	80	NR	0,7	Herbivores
Mala-costraca	*Isopoda*	*Porcellionidae*	48	208	1,6	1,8	Detritivores
		Rhinotermitidae	128	64	4,2	0,6	Detritivores
		Termitidae	114	2 126	3,7	18,3	Engineers
	Total		Σ3,062	Σ11,593	Σ 100	Σ 100	Predators (n = 3 053) Detritivores (n = 1 104) Herbivores (n = 1 714) Engineers (n = 8 784)

NR (Not recorded).

soil engineers (*Formicidae*, *Termitidae*, and *Lumbricidae*). It was followed by the families that are part of the predator group (*Scolopendridae, Theraphosidae, Salticidae*, among others), which suggests an important presence of biological controls. Associated with the high quantity of ind/m^2 of the predator group, low quantity of ind/m^2 was recorded, belonging to families with herbivore functions, some of them being *Scarabaeidae*, *Aphididae*, *Noctuidae* and *Acrididae*.

In the conventional system, the family composition per functionality recorded higher richness of predators with nine. *Theraphosidae* and *Salticidae* were found among the most important due to the quantity of individuals. Regarding the group of detritivores, they were represented by five families, including *Stratiomyidae* and *Tenebrionidae*. With the same number of families the group of soil engineers was identified, *Formicidae* and *Lumbricidae* being the most important ones. The herbivore group, with four, was the least representative in the family composition (table 3).

The difference in family composition, in number as well as in the importance of functional groups between systems, suggests different levels of biological activation of the soil, with advantage for the silvpastoral system.

Higher quantity of macrofauna individuals was recorded in the SPS (11 593), which corresponded, approximately, to four times the recorded quantity in the conventional system, with 3 062. The difference between systems was marked by the number of individuals recorded for the families *Formicidae* (4 150) and *Termitidae* (2 126), which represented 54 % of the ind/m^2 in the SPS (figures 1 and 2).

In the conventional management, the two families with higher dominance, *Formicidae* and *Mutillidae*

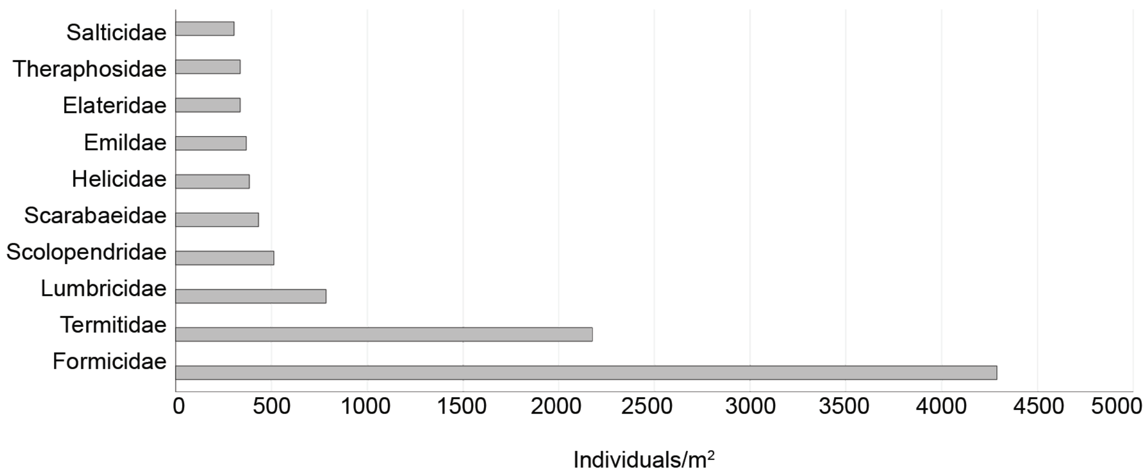

Figure 1. Prevailing families in the silvopastoral system.

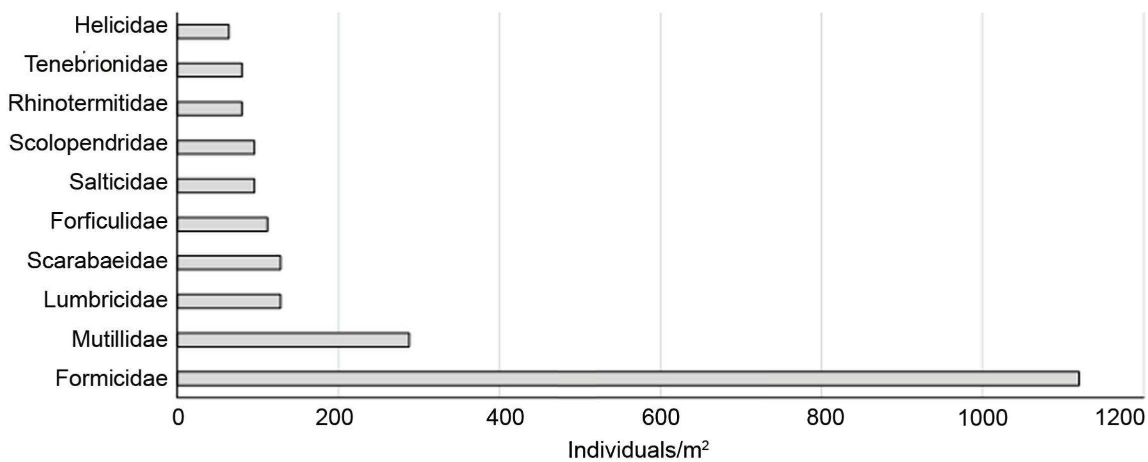

Figure 2. Prevailing families in the conventional system.

(1 258 and 290 ind/m^2, respectively), represented 45 % of the total record of organisms, for which this system had lower dominance of families with regards to the SPS.

A similar performance was recorded in the family density with predominance in the evaluated systems. In both systems, the existence of one to three families with remarkable differences of ind/m^2 was observed, compared with the complementary families of the composition (figures 2 and 3). The similarity between systems was stressed, being *Formicidae* and *Lumbricidae* found among the prevailing families.

Díaz-Porres *et al.* (2014) stated that the quantity of ind/m^2 of the edaphic macrofauna in these families is remarkable, as they were identified in diversified animal husbandry systems, in which the biological activity is increased with the presence of tree and shrub species that incorporate organic matter. Cabrera-Dávila *et al.* (2011) reported that these families perform important ecological functions in animal husbandry systems, which contributes to increase organic matter and improve soil properties.

The families with higher dominance were *Formicidae* (56,9 %), *Termitidae* (14,5 %), *Lumbricidae* and *Scolopendridae*, which perform important functions in the ecosystem, specifically related to the regulation of soil dynamics and its influence on crops. With higher proportion in the trophic group soil engineers the families *Formicidae*, *Termitidae* and *Lumbricidae* were recorded (table 3), common in the results of the edaphic macrofauna monitoring, with proven functionality in soil structure improvement processes. Regarding *Lumbricidae*, Lavelle *et al.* (2003) emphasized its importance in the soil biological activation, specifically due to the construction of biostructures or bioaggregates at certain depth.

The proportion of individuals from the families of soil engineers was different between systems. *Formicidae* recorded higher percentage (41,0 %) in conventional management, compared with the silvopastoral system (35,7 %). The proportion of *Lumbricidae* was higher (7,7 %) in the silvopastoral system, and lower in the conventional management (5,8 %).

In the case of *Termitidae*, the differences in the proportions between systems are more remarkable, with 13,0 % in the SPS and 1,4 % in the conventional management. The herbivore (17,5 %) and detritivore (12,0 %) functional groups showed higher values in

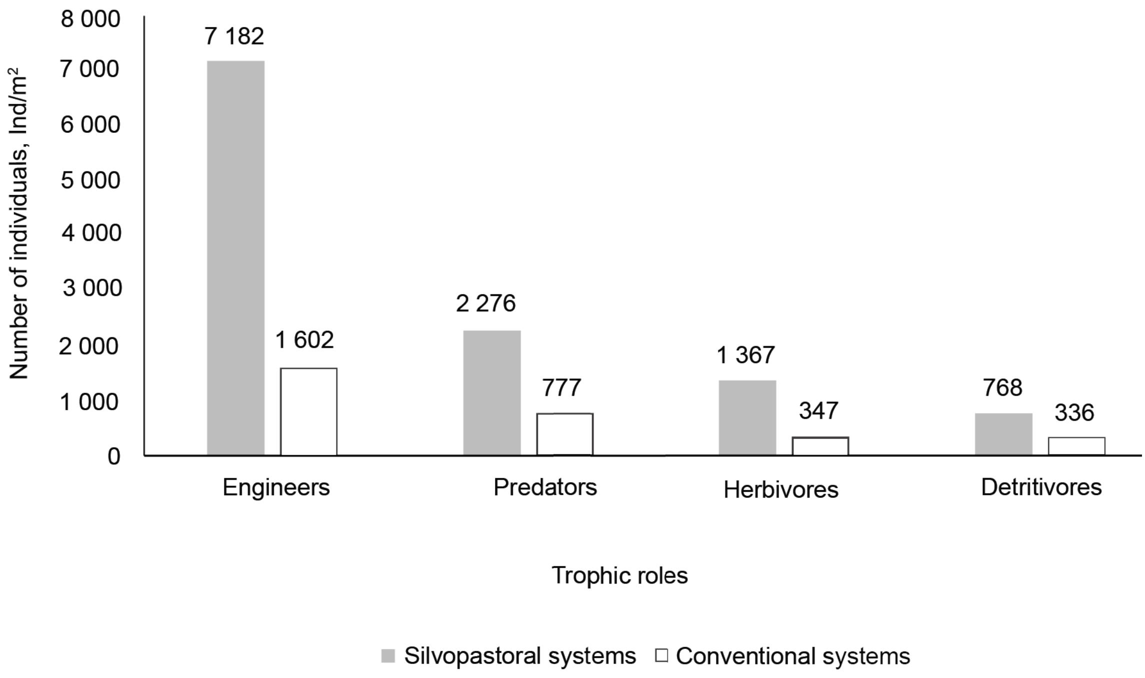

Figure 3. Proportion of macrofauna organisms per trophic roles.

the conventional system, compared with the SPS. In both equal proportion (26,0 %) of the trophic group predators was recorded.

About the families that were not recorded in the conventional system, their low density should be emphasized (16 to 128 ind/m^2), which suggests potential susceptibility in their populations to changes in the management practices, and, thus, in the habitat quality. Among the 13 different families that stood out in the silvopastoral system, the ones that play the role of predation (5), herbivores (5) and detritivores in lower number (3) are highlighted; while the families that were recorded only in the conventional systems were, in higher number herbivores (4), and one with detritivorous role.

The analysis of organism density per sampling depth, as indicator of differences in the biological activation of the soil profile, recorded high concentration of macrofauna in the topsoil, with 5 480 ind/m^2 (47,0 %) in the SPS, and 1 860 ind/m^2 (60,0 %) in the conventional system, and a decrease at higher depth was observed. This behavior has been referred as a pattern in diverse studies associated to the vertical distribution of macrofauna (figure 4).

In figure 4, the highest density of edaphic macofauna was shown in the first 10 cm of the soil. At the level of the first layers, the reduction in density of organisms was marked in the conventional system (with reduction higher than 50,0 %), compared with the SPS, where the reduction of density between the surface and from 0 to 10 cm was 17,0 %.

Similar results to the ones in this study were reported by Noguera-Talavera *et al*. (2017), when analyzing the distribution of the macrofauna in two soil management systems. These authors suggested a higher concentration of individuals in the agroecological system, as well as higher density at the level of all the evaluated depths. They linked the results, partly, to soil management practices, due to the addition of organic fertilizers, which improve the habitat conditions for the edaphic macrofauna.

Conclusions

The highest richness of families and quantity of individuals were obtained in the silvopastoral system, which proves its importance in animal husbandry exploitations.

The predominance of families of the ecological group soil engineers and predators shows the existence of processes that transform the soil characteristics, and of self-regulation mechanisms of potential pest populations in the evaluated systems.

The predominance and functionality of the families per sampling depth prove the hypothesis of high concentration and higher biological activity in the first 10 cm of soil profile, as well as a remarkable balance in the predation and detritus accumulation functions.

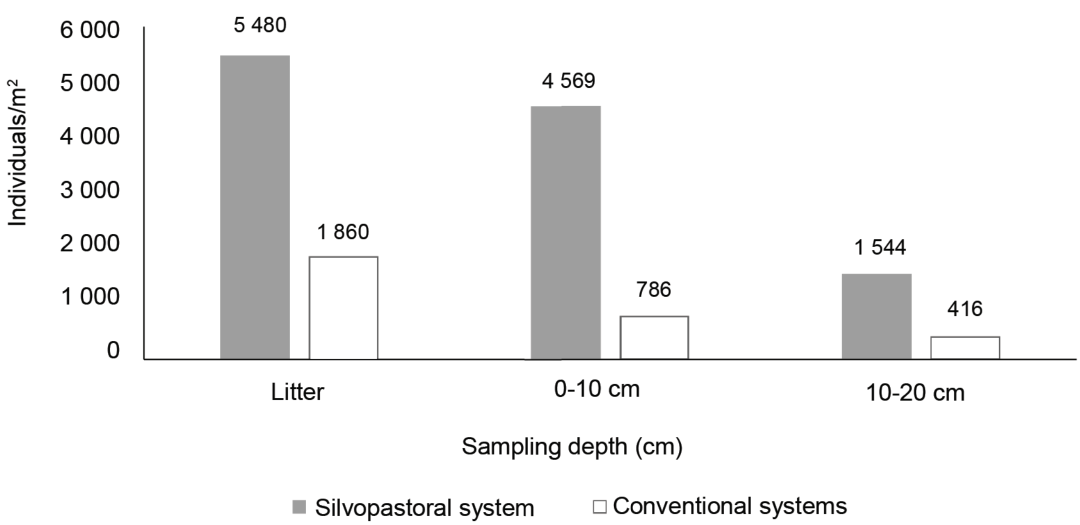

Figure 4. Quantity of organisms (ind/m^2) of the edaphic macrofauna per sampling depth and animal husbandry system.

Acknowledgements

The authors thank the Doctoral Program on Agroecology of the National Agricultural University-Nicaragua and the Latin American Society of Agroecology for the support in the studies that led to this article.

Authors' contribution

- Camilo del Carmen Gutiérrez-Bermúdez. Conducted the experiments, the data collection. In addition, prepared the paper for its publication.
- Bryan Gustavo Mendieta-Araica. Conceptualized the research idea, revised the statistical analyses and adapted the manuscript according to the referees' suggestions.
- Álvaro José Noguera-Talavera. Conducted the statistical analysis and revised the manuscript.

Conflicts of interests

The authors declare that there are no conflicts of among them.

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